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FILING DATE: ***December 12, 2003***
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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a r quest for filing a PROVISIONAL APPLICATION FOR PATENT und r 37 CFR 1.53(c).

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INVENTOR(S)

Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
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☐ *Additional inventors are being named on the _______ separately numbered sheets attached hereto*

TITLE OF THE INVENTION (500 characters max)

Devices and Methods for Microcontact Printing

Direct all correspondence to: **CORRESPONDENCE ADDRESS**

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ENCLOSED APPLICATION PARTS ***(check all that apply)***

☑ Specification *Number of Pages* 12
☐ Drawing(s) *Number of Sheets* ______
☐ Application Data Sheet. See 37 CFR 1.76
☐ CD(s), Number ______
☐ Other (specify) ______

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Respectfully submitted,

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TYPED or PRINTED NAME ROBERT HAUSHALTER

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Date 12/12/03

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TRANSMITTAL FORM

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Application Number	
Filing Date	12 December 2003
First Named Inventor	Robert Haushalter
Art Unit	
Examiner Name	
Attorney Docket Number	

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ENCLOSURES (*Check all that apply*)

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Filing Date	12 December 2003
First Named Inventor	Robert C. Haushalter
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Art Unit	
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1002	330	2002	165	Design filing fee	
1003	520	2003	260	Plant filing fee	
1004	750	2004	375	Reissue filing fee	
1005	160	2005	80	Provisional filing fee	80.00

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2. EXTRA CLAIM FEES FOR UTILITY AND REISSUE

			Extra Claims		Fee from below		Fee Paid
Total Claims		-20** =		X		=	
Independent Claims		- 3** =		X		=	
Multiple Dependent						=	

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
1202	18	2202	9	Claims in excess of 20
1201	84	2201	42	Independent claims in excess of 3
1203	280	2203	140	Multiple dependent claim, if not paid
1204	84	2204	42	** Reissue independent claims over original patent
1205	18	2205	9	** Reissue claims in excess of 20 and over original patent

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1051	130	2051	65	Surcharge - late filing fee or oath	
1052	50	2052	25	Surcharge - late provisional filing fee or cover sheet	
1053	130	1053	130	Non-English specification	
1812	2,520	1812	2,520	For filing a request for *ex parte* reexamination	
1804	920*	1804	920*	Requesting publication of SIR prior to Examiner action	
1805	1,840*	1805	1,840*	Requesting publication of SIR after Examiner action	
1251	110	2251	55	Extension for reply within first month	
1252	410	2252	205	Extension for reply within second month	
1253	930	2253	465	Extension for reply within third month	
1254	1,450	2254	725	Extension for reply within fourth month	
1255	1,970	2255	985	Extension for reply within fifth month	
1401	320	2401	160	Notice of Appeal	
1402	320	2402	160	Filing a brief in support of an appeal	
1403	280	2403	140	Request for oral hearing	
1451	1,510	1451	1,510	Petition to institute a public use proceeding	
1452	110	2452	55	Petition to revive - unavoidable	
1453	1,300	2453	650	Petition to revive - unintentional	
1501	1,300	2501	650	Utility issue fee (or reissue)	
1502	470	2502	235	Design issue fee	
1503	630	2503	315	Plant issue fee	
1460	130	1460	130	Petitions to the Commissioner	
1807	50	1807	50	Processing fee under 37 CFR 1.17(q)	
1806	180	1806	180	Submission of Information Disclosure Stmt	
8021	40	8021	40	Recording each patent assignment per property (times number of properties)	40
1809	750	2809	375	Filing a submission after final rejection (37 CFR 1.129(a))	
1810	750	2810	375	For each additional invention to be examined (37 CFR 1.129(b))	
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SUBMITTED BY				(Complete *(if applicable)*)	
Name (Print/Type)	Robert C. Haushalter	*Registration No. (Attorney/Agent)*		*Telephone* 408-353-5250	
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Devices and Methods for Microcontact Printing

This provisional patent application discusses new methods, devices and improvements to an area know to those skilled in the art as Microcontact Printing.

(1) Methods for Print Tip Thinning

It is desirable to make very small spots (≤100 μm) of DNA, or other materials, for some applications. However, it seems as though the wafer must be thinned to make spots as small as required. Because the pins are cut from the wafer using an anisotropic plasma etch (DRIE; see original application), which cuts perpendicular trenches to the wafer surface, and the plane of the cut pin lies in the plane of the wafer during fabrication, one of the tip dimensions has to correspond to the wafer thickness in the absence of any thinning. However, it is not practical to make, for example, a 100μ tip out of a 100μ thick wafer, as the 100μ thick wafers are very difficult to handle because of lack of mechanical stability. Thus a thinning operation is required to reduce the tip size below that of the starting wafer thickness so as to have both a small tip and the requisite mechanical stability.

One of the most important goals is tip size reduction and we have designed a relatively simple and inexpensive micromachining procedure that will allow the preparation of any arbitrarily sized tip from a given wafer. This is extremely important as now a thicker wafer (up to the ~500μ limit of the DRIE procedure) can be utilized which results in a thicker shaft on the pin. The thicker shaft not only provides greater strength but allows the fabrication of a larger reservoir.

The new procedure uses either a combination of wet KOH and DRIE etching, or DRIE etching alone, to sculpt the tip to the desired shape by selective thinning of certain regions of the wafer before the pins are cut from the die with DRIE. Figure 1 shows that four basic tip shapes can be fabricated depending on whether a wet etch or DRIE is used for the thinning operation which will give depressions with sloped or vertical sidewalls.

One example of wet etched design choice is shown in Fig. 1 A and B. Unlike DRIE operations, the wet etch procedure can be run in a parallel fashion. By using either a double or single sided etching procedure the pin tip would be disposed symmetrically or asymmetrically, respectively, between the two large faces of the starting wafer (Fig. 1 A, B). A schematic illustration of the pin layout, relative to the wet etched pits, is shown in Fig. 2, with a layout of the pins on the same (Fig. 2A) and opposite (Fig. 2B) sides of the wafer. The schema where the pin is laid out on the same side of the wafer as the thinning

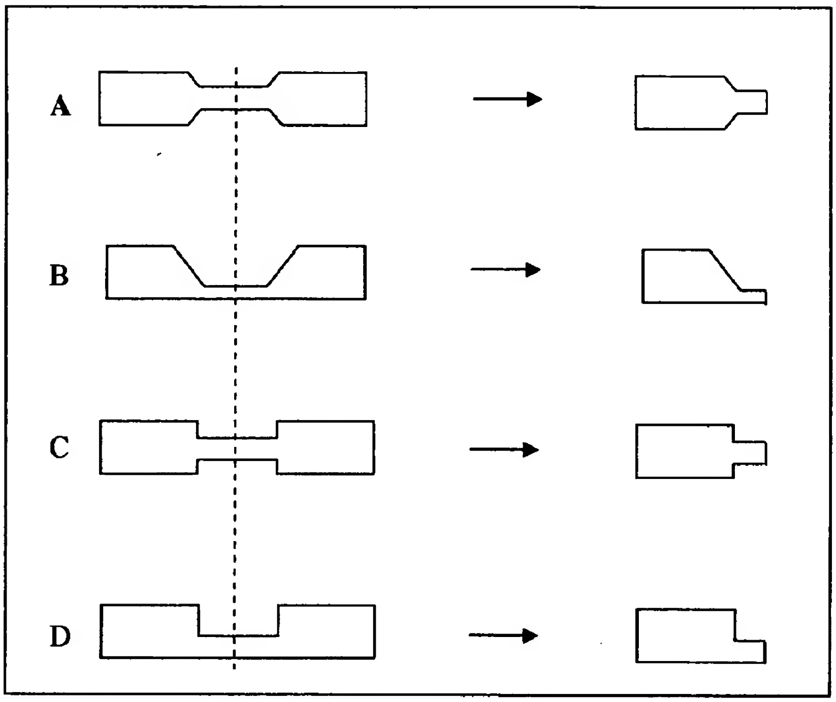


Fig. 1 Designs for the fabrication of printing tips thinner than the substrate using a thinning operation that precedes the final DRIE cutting of the pins from the wafer. The left hand column shows the thinning type and the dotted line represents a cut that produces two identical tips one of which is shown in the right hand column. The depressions in A and B result from wet etching while C and D result from DRIE procedures. Alternatively, the structures shown in the right hand column can be cut individually from the wafer.

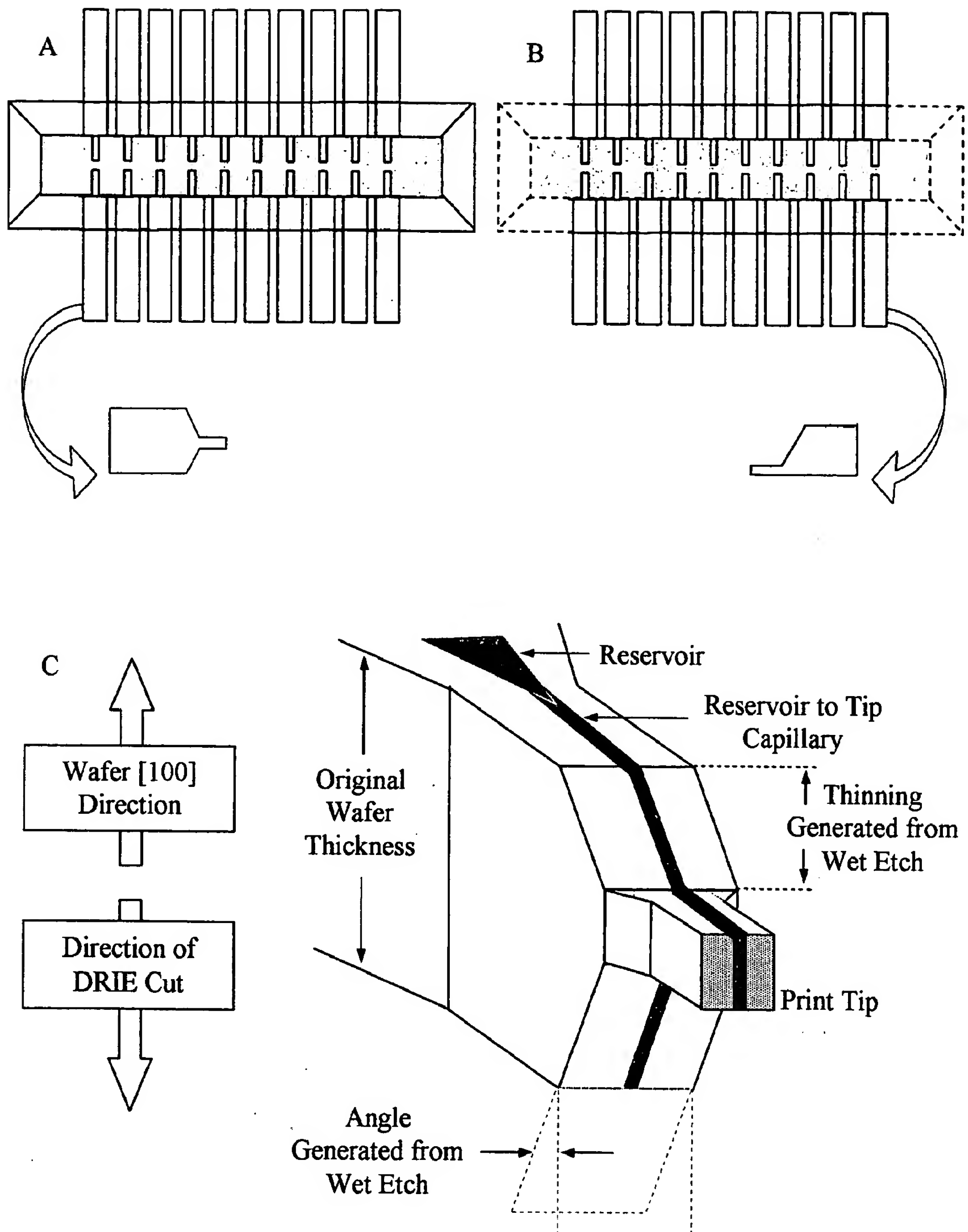


Fig. 2 One method of reducing the print tip dimensions. A and B show a schematic of the pin tip shape obtained with the thinning on both sides (A) or on a single side (B) opposite the pin pattern. The Fig. 2B layout produces the asymmetric tip shown in Fig. 1B. Part C shows the symmetric print tip that results when the pins are cut from a substrate that has been thinned on both sides (Fig. 2A) with a KOH etch.

depression requires the use of simple projection lithography. When the pattern to be cut by the DRIE step is on the opposite side of the depression, only routine lithography is required. This latter procedure does generate the asymmetrically disposed tip (Fig. 2B). Because of the holder design discussed below, it is believed that the asymmetric tips will not undergo any horizontal deflection upon application of force in the *z* direction (perpendicular to wafer plane). The asymmetric tips are easier to fabricate and require fewer steps and will therefore be less expensive.

At the expense of adding an additional masking/etching procedure into the overall process, the square print tip can be fashioned into an octagonal tip that approximates the more ideal round shape if reshaping of the deposited spot proves to be necessary. As shown in Fig. 3, a first pit is wet etched into both side of the wafer in a thinning operation that determines the ultimate horizontal thickness of the print tip.

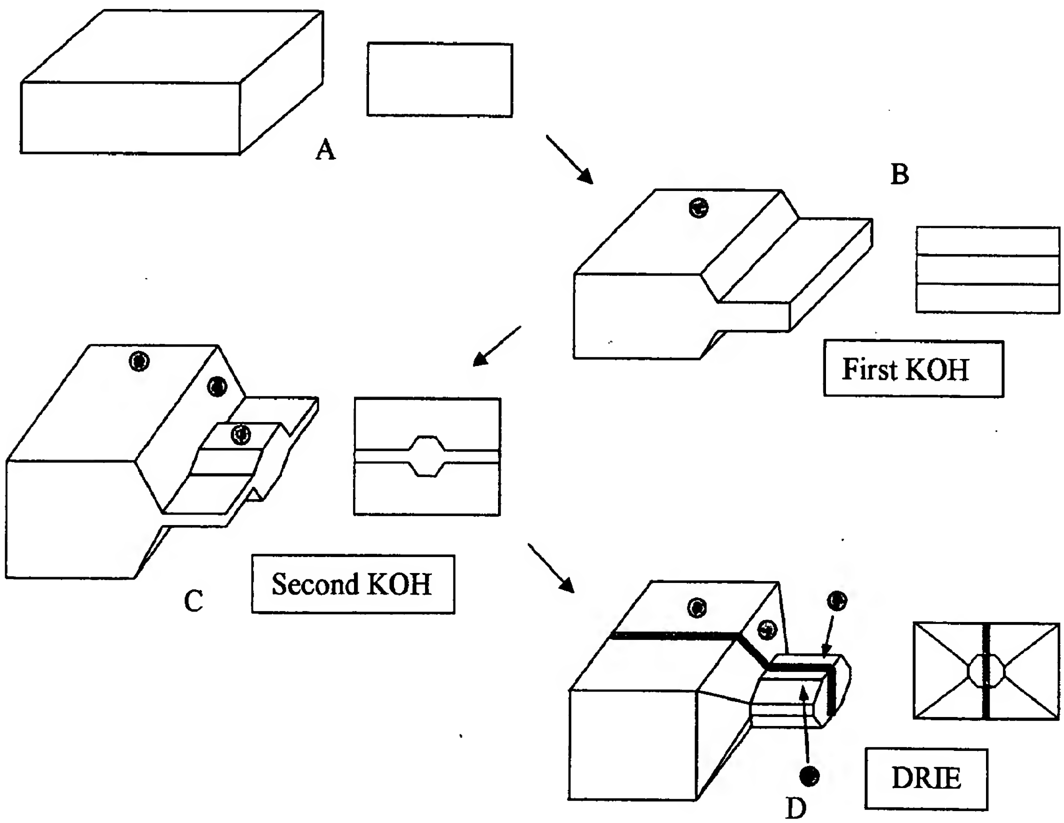


Fig. 3 An octagonal print tip can be micromachined by using two wet etch operations etch and one DRIE step. The red circles represent surfaces that are covered with an etch stop layer. For the KOH etches, SiO_2 will suffice for this etch depth but Si_3N_4 can be used if needed. The heavy solid line in D is the capillary channel, fabricated by DRIE with photoresist or oxide etch stop, connecting the reservoir and print tip.

Another method to thin the tips to a smaller side relies on the use of DRIE for all of the etching steps as shown schematically in Fig. 4. For this method, the entire outline of the pins, channel and reservoir, as well as the area to be thinned on the tip to reduce its

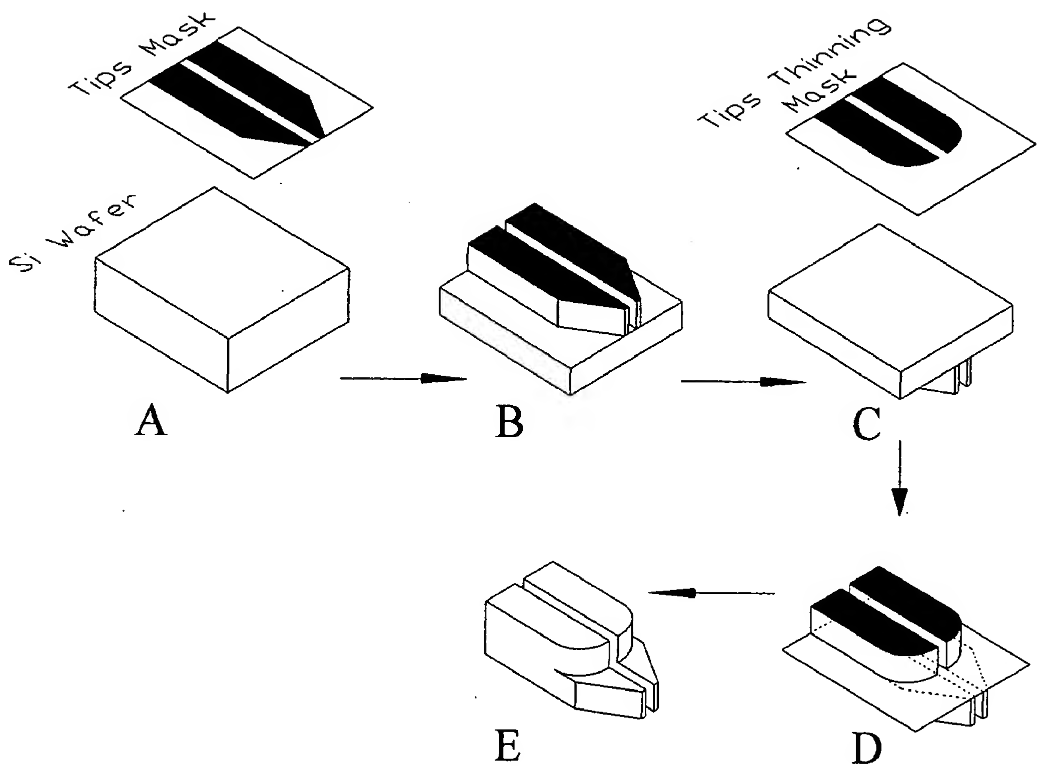


Fig. 4 Process flow for the micromachining of Si pins using two DRIE operations. The process starts with a 200μm Si wafer (A), patterned with tips mask (A), and etched 100μm using DRIE (B). The wafer is then flipped upside down (C), patterned with the thinning mask (C), and etched another 100μm using DRIE process (D). The pin tip along with the thinning region is shown in E. The pin tips can be made of any arbitrary size by varying the etch depths using the same photomasks.

size, is cut by DRIE on the first side of the wafer. Next, the opposite side of the wafer has the pattern to be cut aligned to the etch on the first side by standard double sided mask alignment techniques using infrared radiation to see through the wafer. After suitable patterning, processing and etching, the pin with the suitably thinned tip (Fig 4E) is now completely etched away from the die except for a specially micromachined breakaway attachment point (Fig. 5B).

Some examples of the type of pin that can be made using this all-DRIE process are shown in Fig. 5. Note the step that defines the difference in heights between the thinned and unthinned portion of the tip is not straight but rather is curved (Fig. 5A-D). In this case the curve approximates a section of an ellipse (red ellipse in Fig, 5F) which assists in distributing the stress of the thinning discontinuity more widely than a linear cut would. This shape also has an additional added benefit in terms of directing any printing fluid on the outer pin surface into the printing tip of the pin which is an important

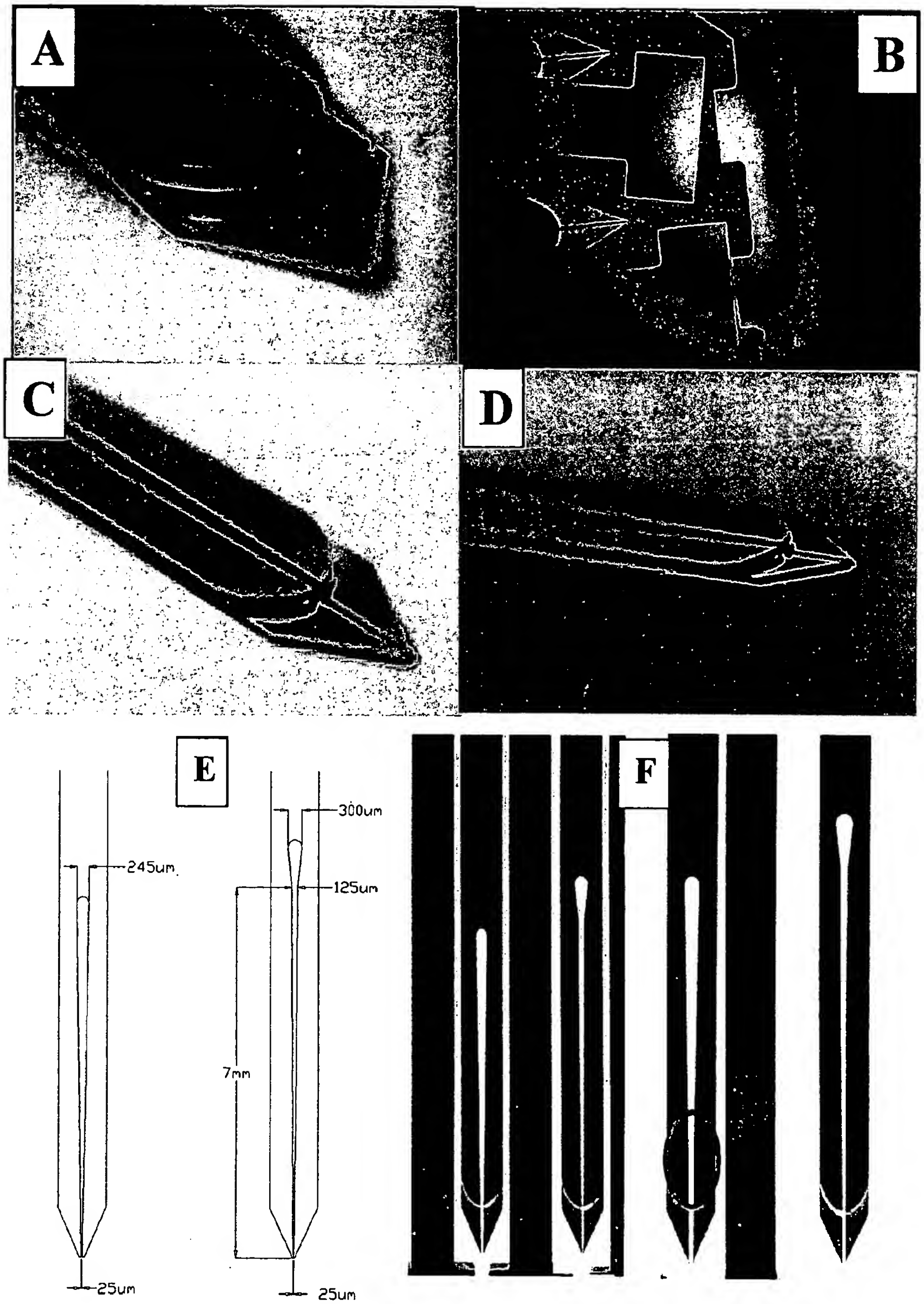


Fig. 5

factor in determining how soon after filling the pin and beginning to print does the printed spot size stabilize as discussed in section 6 (data containing variability in printed spot size cannot be used and generates waste of sample and time).

Depending on how deep the relative etch is on the two sides of the wafer different tip dimensions can be obtained from the same photomask used to generate the pin patterns. As shown in Fig. 6, the total wafer thickness (Fig. 6A) is the thickness of the pin shaft (in this case 200 μm), the depth of the cut on the top surface is shown in Fig. 6B and the thickness of the tip in one dimension is shown in Fig. 6C. The tip dimensions were covered in our previous application and a section below discusses some new non-flat improvements to the flat tip designs.

In summary, several methods are available to thin the tips of the micromachined silicon microcontact printing pins in order to print smaller spots of DNA, protein and other materials.

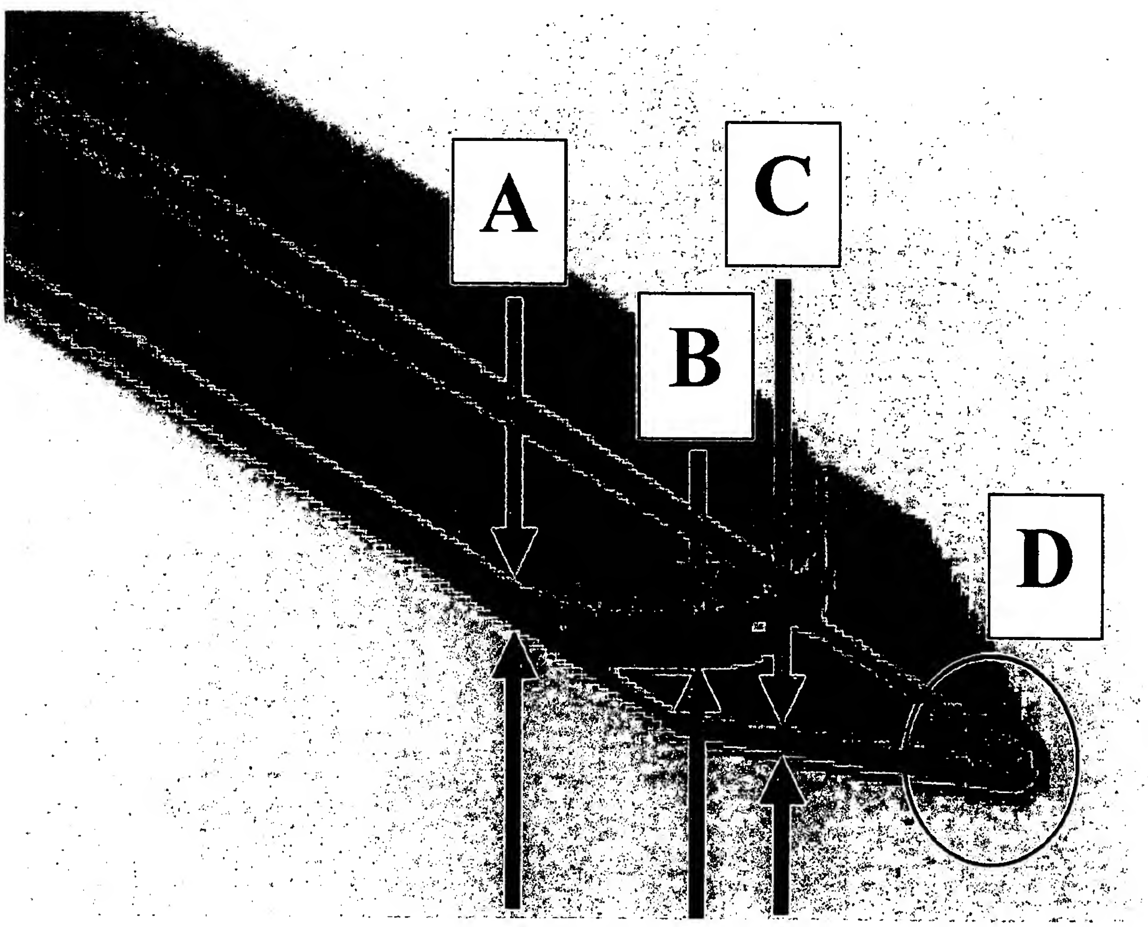


Fig. 6

(2) Control of the Print Tip Pressure on the Substrate

In the most common way to print microarrays, the printing pins are made from stainless steel and are 1/16" in diameter and 2-3" long with a metal collar press fitted onto one end. The pins are held in place for printing by placement into through holes in a metal block and prevented from falling all the way through by said metal collar (Fig. 7). When the suspended pins are lowered onto a substrate, they lift up within the holder when the tip touches the surface of the printing substrate.

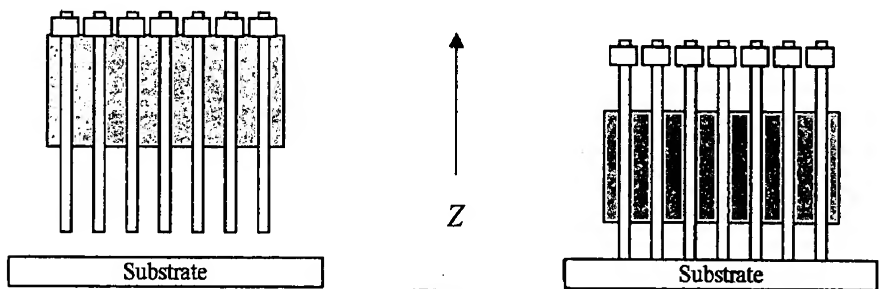
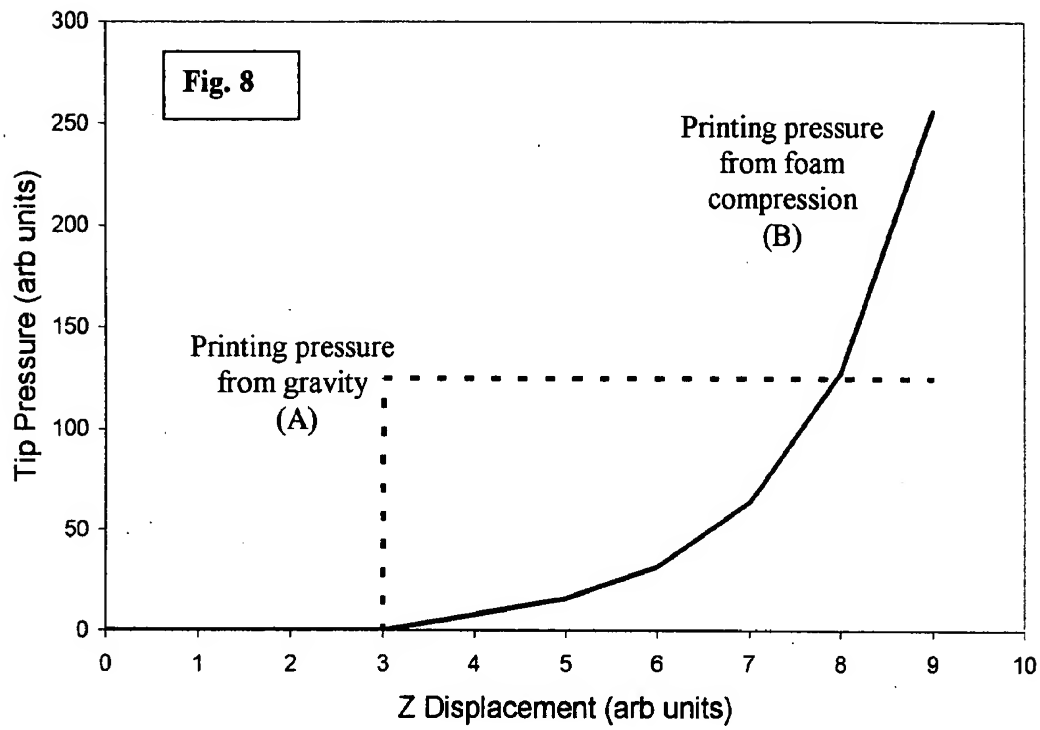


Fig. 7

As shown in Fig. 8, the floating pins produce a tip pressure vs z displacement relationship that gives a constant amount of pressure no matter what the z deflection because the pressure is generated from the weight of the pins which is constant.

Since the microcontact printing process is related to printing with a rubber stamp in some respects, it stands to reason that there is an optimum pressure required to give the most uniform and consistent printed spots. With the floating pin type holder, there is no provision for varying the print tip pressure except for increasing or decreasing the weight of each pin.

In an improvement of the gravity method of forcing the pins onto the substrate, the use of elastomeric membranes or foams is highly advantageous to provide the proper pressure required for printing. When an array of pins with coplanar tips in a holder is covered with a piece of elastomeric foam of some thickness, and the pins used by pressing them against the substrate surface to be printed, the amount of pressure on the tip increases as the z displacement of the holder increases (Fig. 8B). It is also obvious from Fig. 8 that inducing the printing pressure from a deformable elastomeric source allows the application of very small amounts of pressure or larger amounts than the gravity methods, thereby allowing the selection of the optimum printing pressure. It is clear as well that by choosing judiciously among parameters such for (a) foam: overall thickness, foam cell size, cell density in the foam, the foam material and the foam backing that many different print pressures can be obtained or (b) elastomeric membrane: elasticity of membrane, membrane thickness, how tight when mounted, etc.



It is clear that the use of the elastomeric materials to provide variable and correct printing pressures is a large improvement over the current practice.

(3) Geometric factors influencing delivery of the printing fluid from the reservoir to the printing tip

It is absolutely critical for the smooth, accurate and controllable delivery of the printing fluid to the printing tip from the reservoir, which in turn is essential for the printing of small and uniform spots, that the reservoir, delivery channel between the reservoir and printing tip be of precise dimension and shapes. The channel at the bottom of the exit can be from 10 nm to several hundred microns depending on how thick the tip is. Fig. 5E shows the dimension of two typical reservoirs and channels while Fig. 5F is a photomicrograph of some of the fabricated silicon pins showing the reservoirs and channel shapes and dimensions.

One of the most important aspects of the channel shape is that it must always decrease in width as it gets closer to the print tip in order to draw the fluid toward the print tip and keep it wet as the printing fluid is depleted. If the channel is of a constant width/diameter, a meniscus will form as the initial fluid on the print tip is depleted and retreat up the channel away from the print tip.

Another important aspect is the depth of the channel, which is 200 μm in this case but could range from 10nm to several millimeters in depth.

Still another important feature of the channel and reservoir in the micromachined pins is that it can be made any volume between 10^{-2} femtoliters and tens of microliters thereby allowing just the amount to be subsequently printed to be taken up into the reservoir and channel thereby minimizing waste of valuable samples like DNA or proteins.

(4) Non-flat print tip shapes

While some of the current metal pins claim to have flat printing tips, it has been found to be advantageous for printing very high quality spots that the printing tips can be non-flat including curved, scalloped, sloped and otherwise textured. Examples are shown in Fig. 9A and 9B. The shape of the tip greatly influences the shape of the deposited spots.

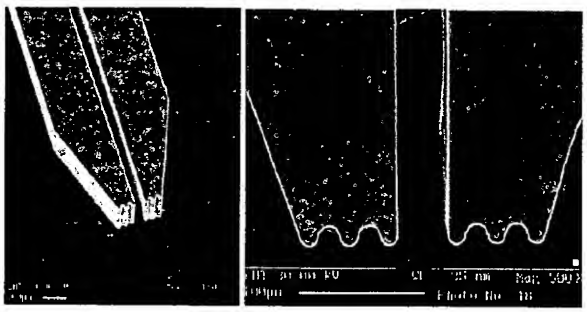


Fig. 9A SEM picture of a scalloped Si pin tip style with a 200 x 200μm pin tip.

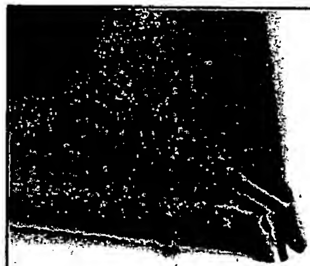


Fig. 9B Curved tip

(5) Advantages of well formed, thick and pure oxide pin coatings

After any etching or micromachining operation, the surface of the silicon oxidizes upon exposure to the atmosphere to form a rather thin (20-60Å) layer of a structurally ill defined material called the "native oxide". Silicon with only the native oxide is sometimes difficult to wet and hard to clean. However, when silicon is treated with steam at 900-1000°C, a very dense, pure, conformal coating of SiO_2 is formed

The thick continuous oxide coating protects the pins from certain chemicals and provides a surface that is easily cleaned and regenerated by heating in the atmosphere or under oxygen. These heating treatments are particularly effective at removing any biological or organic impurities.

Still another advantage of the thick SiO_2 coatings on the silicon microcontact printing pins is that from a surface chemistry viewpoint, the SiO_2 surface is essentially identical to glass. This is very important because there is a great deal of chemical literature associated with the chemical derivitization of glass surface. By attaching certain chemicals to the surface of the SiO_2, the surface properties of the printing tools can be modified to alter the wetting properties or biological species (e.g. proteins, antibodies or DNA) can be attached to the SiO_2 surface to greatly increases the molecular specificity.

(6) Elimination/minimizing of prespotting phenomenon

Prespotting phenomenon: When the pins are dipped in the printing solution for fluid pickup, some of the fluid sticks to the outside walls of the pins. Eventually when the printing starts the solution sticking to the walls of the pins gradually gets deposited on to the substrate along with the solution from the reservoir drastically increasing the spot size. Hence "pre-spotting" is required to remove sample from the exterior of the pin tip so that only the solution from the reservoir/quill is dispensed to the array. This is a considerable waste of time and expensive samples.

This problem is eliminated by the thinning design as discussed earlier in section 1. The extra sample sticking to all the exterior walls of the pins is directed to the thinned region (as shown in Fig. 10A) instead of towards the pin tips as in the case of non thinned tips (Fig. 10B). The spot profile from the first to the last spot printed from a single sample uptake using the two types of pins (Fig. 10) is shown in Fig. 11. As shown in Fig.11A the pre-spotting phenomenon is significantly reduced compared to Fig. 11B.

This could also be achieved by having grooves (leading to the reservoir channel) on the external walls of the pin type shown in Fig 10.B.

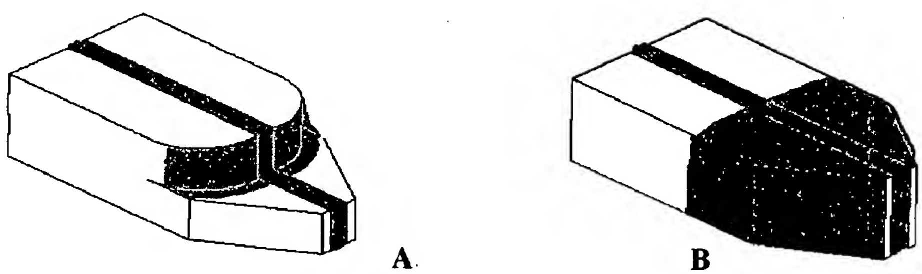


Fig. 10 Schematic representation of a thinned (A) and non thinned tip (B) and the printing fluid in the reservoir channel (red)

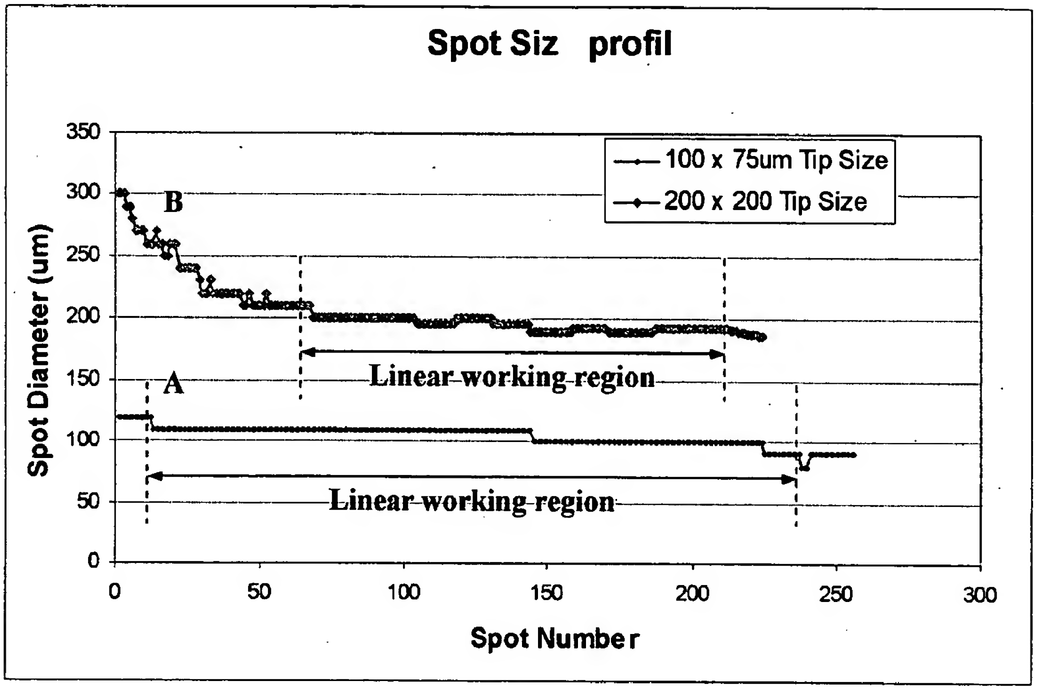


Fig. 11 Spot size profile of a A) thinned pin (blue) vs B) non thinned pin (green).